Subject: Distilled Notes from the ASTM E08.04.06 Workshop on Residual Stress in Design and Sustainment
Date: 4 November 2021

- Six Excellent Presentations
    - Dr. Dale Ball (Lockheed Martin, Ft. Worth) – development diary from the SAE RS in forgings spec
        - Insights into RS requirements and art of the possible
        - Considerations for how this is going to work practically from design engineer down to QC
    - Dr. Mark James (Howmet) – review of ICME and RS prediction along with a glimpse of upcoming ASTM standards
        - Review of programs like MAI BA-11 and LM-7
        - Covered why divorcing RS data from FCG rate data is so critical to what we are going to need moving forward
        - Glimpse at draft ASTM E647 appendices that can help accomplish this
    - Dr. Mike Hill (UC Davis) – excellent insight into types and sources of RS as well as the stable of RS meas techniques available
        - Great points on what we should and shouldn't dictate in a guide like this
            - User needs to be aware of how they are trying to use RS along with tolerances and, magnitudes and trends
            - "Good enough" is truly a subjective concept
    - Dr. Michael Gorelik (FAA) – review of existing guidance and considerations that need to be taken into account for considering and including RS in airworthiness/certification
        - Advocated for inter-industry RS planning roadmap (details below)
        - *From TJ: I believe this could be the future of ERSI – helping to develop and execute this roadmap*
    - Dr. Patrick Raynaud (NRC) – detailed review of the four phase NUREG welding program that intensively modelled, validated, and derived guidance from RS development in welding processes for reactor nozzles
        - Excellent review of impact on analysis for different types/fidelities of data
        - Great vision from conception to resulting guidance in NUREG-2228
    - Mr. Casey Gales (John Deere) – review of several impact studies of various types of welding and residual stress measurement techniques. Very useful and practical insights into test program considerations and how they will effect actual designs
        - Multi-pass welding simulations for simple loading conditions and how complicated the RS state can be
        - Evaluation of multiple measurement and lifing techniques
- High-Mid Level Takeaways
    - Inter-industry conversation/collaboration essential to widespread adoption of RS
        - All of us have been working the problem from our own perspectives
        - All of us have insights others can benefit from

- ASTM E08.04.06 Task Group (RS in Design and Sustainment Best Practices Guide) should attempt a general framework for RS in lifing analyses
  - Layer in conservatism with each input
    - i.e. – rate data, cyclic interactions, RS estimates, etc.
    - No one piece, if absent/erroneous, breaks a positive safety margin
  - Small companies don't have expertise to interpret general guidance
    - Rely on standards orgs to provide "cookbook" style guidance
- Tensile RS contributions to K well understood/proven, compressive not so much
  - Contact mechanics cloud this, amongst other factors
  - Work needs done here: potentially fruitful R&D area for next few years
- Add additional case example to Guide
  - Possibly a negative use case (RS don't fix the lifing shortfall)
  - Possibly an example where 1D and 2D analyses of same thing have very different lifing outcomes
    - BA-11 bulkhead bulk RS example was brought back up
- Verification and validation are critical AND not well defined anywhere
  - Could be a good place for guidance on how to assess model validity
    - NOT if it meets certain industry guidelines
    - Testing guide – X number of tests, w/ statistics, and correlation ratio of Y [OR] must be within Z band of confidence
  - Step 1 – suggestions on validity and needed data (w/in scope)
  - Step 2 – respective industry specific data requirements (NOT w/in scope)
  - ASTM E08.04.04 (V&V best practice guide; POC - E. Tuegel)
- Statistics, Probabilistics, and UQ will need to be a major portion of this guide
  - NUREG-2228 base for statistical analysis
  - Really only way to handle variability at all levels, including propagating up to end analysis (i.e. – RS variability, FCG rate variability, etc. and then how they all combine to affect your lifing analysis)
  - Can handle either deterministically and/or w/ Stat/prob
    - Could incorporate a variety of approaches: guidance could be flexible and provide levels of accuracy/level of accounting
    - If using deterministic methods, need to incorporate sensitivity analyses as a bare minimum
  - ASME V&V 40 document (modelling of submissions of medical devices for cert.) has great section on when/how deep stat/prob analysis should go
- Conflicting RS measurements and what to do
  - Gathering more data is always a good answer, so long as practical
  - Can observe secondary effects (i.e. – FCG/distortion)
    - Can work backward to try and make sense of the data
  - Usually measuring something else (NOT RS)
    - Understanding underlying mechanics of techniques critical to getting good data

- Need to recognize that models are great sources of data
  - Master Road Map for R&D/Standards/Regulation development planning AND cross-industry communications (Recommneded by M. Gorelick)
    - Should include:
      - Vision of a future state, including benefit analysis
      - Maturity assessment of key current capabilities
      - Gap analysis
      - Technical plan to address gaps
      - Would require multiple "swim lanes"
      - Could be used as a planning and comm tool
        - Develop consensus
        - Engage stakeholders